



MODELLING FOR SEA TURTLE NESTING HABITAT USING GIS AND MULTICRITERIA EVALUATION

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Problem

Sea turtles are endangered species.

Their nesting habitats have been reduced, interfered with.

Old nesting habitats may be restored if they can be identified.

Changing climate also may have rendered current nesting sites useless.

Where could new nesting sites be found?

How can we find them?

OBJECTIVE

To identify potential sea turtle nesting habitat areas in Rio de Janeiro's coastline using biotic and abiotic variables supported by remotely sensed images in a Geographic Information System environment

The following species of sea turtles were considered in this study



Loggerhead -

C.caretta (Linnaeus, 1758)
(IUCN Red List)



Green

E.imbricata (Linnaeus, 1766)
(IUCN Red List)

Leatherback

D. coriacea (Linnaeus, 1766)

Critically endangered - (IUCN Red List)



Danielle Moraes











TO
FAMAR

PETROBRA





The start –

a search for
environmental
preferences

50 variables were found
!

	PREF. DESOVA / SP DE TART.MAR.	CC	DC	B	CM	LO	TODAS SP	REF.BIBLOG.
1	SEM ILUMINAÇÃO	CC	DC	EI	X	LO	X	MORTIMER,J.A . 1995
2	LIVRES DE PEDRAS	CC	DC	EI	CM	LO	X	MORTIMER,J.A . 1995
3	APROXIMAÇÃO DA COSTA ABERTA	CC	DC	EI	CM	LO	X	MORTIMER,J.A . 1995
4	APROXIMAÇÃO DA COSTA ARENOSA	CC	DC	EI	CM	LO	X	MORTIMER,J.A . 1995
5	TODOS OS TIPOS DE AREIA	CC	DC	EI	CM	LO	X	MORTIMER,J.A . 1995; GARMESTANI ET AL.2000
6	FÁCIL ACESSABILIDADE DO MAR	X	DC	EI	CM	LO	X	MORTIMER,J.A . 1995
7	PLATAFORMA ALTA O BASTANTE	X	DC	EI	CM	LO	X	MORTIMER,J.A . 1995; GARMESTANI ET AL.2000
8	BAIXO PERFIL DE PRAIA	X	DC	EI	CM	LO	TODAS	DIEZ,C.E & OTTENWALDER,J.A . 2000
9	DECLIVIDADE DA PRAIA ALTA	CC	X	X	CM	LO	X	WOOD,D.W & BJORNDAI,K.A . 2000
10	LIVRES DE VEGETAÇÃO	CC	X	EI	X	LO	TODAS	DIEZ,C.E & OTTENWALDER,J.A . 2000
11	VEGETAÇÃO DE FRENTE DA PRAIA	X	DC	X	X	LO	X	MORTIMER,J.A . 1995
12	PRAIAS LARGAS	CC	DC	EI	X	LO	TODAS	GARMESTANI ET AL.2000
13	PRAIAS LONGAS	CC	DC	EI	CM	LO	X	MORTIMER,J.A . 1995
14	APROXIMAÇÃO DA COSTA PROFUNDA	CC	X	EI	CM	LO	X	MORTIMER,J.A . 1995; DIEZ,C.E & OTTENWALDER,J.A . 2000
15	LIVRES DE AMONTOADOS DE ROCHA	CC	X	EI	X	LO	X	GARMESTANI ET AL.2000
16	LIVRES DE OBSTRUÇÃO SUBMERSAS	CC	X	EI	CM	LO	X	DIEZ,C.E & OTTENWALDER,J.A . 2000
17	AFLORAMENTOS DE RECIFES	X	DC	X	CM	LO	TODAS	MORTIMER,J.A . 1995; MILLER, J. D. et al. 2003
18	AFLORAMENTOS DE ROCHAS	X	DC	X	CM	LO	TODAS	MORTIMER,J.A . 1995; MILLER, J. D. et al. 2003
19	PRAIAS ATRAS DE BANCOS DE LAMA(MARÉ)	CC	DC	EI	CM	X	TODAS	MORTIMER,J.A . 1995
20	SOMBREAMENTO	CC	DC	X	X	LO	TODAS	GARMESTANI ET AL.2000
21	AREIA SILICOSA	X	DC	EI	X	LO	TODAS	MORTIMER,J.A . 1995
22	PRAIAS COM DUNAS	X	DC	EI	CM	LO	X	MILLER, J. D. et al. 2003; CAMHI,1993
23	PRAIAS EXPOSTAS	CC	DC	EI	CM	LO	X	FISH,M.R. ET AL.2005
24	ACIMA DO NÍVEL MARÉ ALTA (1 A 3 M)	CC	DC	X	X	LO	X	WOOD,D.W & BJORNDAI,K.A . 2000; FISH,M.R. ET AL.2005
25	AREIA MACIA (PENETRABILIDADE)	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
26	PRAIAS ARENOSAS	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
27	PRAIAS SILENCIOSAS	CC	DC	EI	CM	LO	X	MILLER, J. D. et al. 2003
28	LONGE LENÇOL D'ÁGUA (ALTA)	X	DC	EI	CM	LO	TODAS	FISH,M.R. ET AL.2005
29	AREIA QUE FACILITE DIFUSÃO DE GÁS	X	DC	EI	CM	LO	TODAS	MORTIMER,J.A . 1996
30	AREIA FINA	X	DC	EI	CM	LO	TODAS	GARMESTANI ET AL.2000
31	AREIA ÚMIDA	X	DC	EI	CM	LO	TODAS	GARMESTANI ET AL.2000
32	BAIXOS NÍVEIS DE SALINIDADE	CC	DC	EI	X	LO	TODAS	MILLER, J. D. et al. 2003
33	TEMP. AREIA ACIMA DE 21,2°C	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
34	ALTA TEMP. SUP. DA PRAIA	X	DC	EI	CM	LO	TODAS	W & BJORNDAI,K.A . 2000; STONEBURNER, D. L. & RICHARDSON, J.
35	PRAIAS DE BARLAVENTO	CC	X	EI	CM	LO	TODAS	MILLER, J. D. et al. 2004
36	PROFUNDIDADE DA AREIA > OU = 60 CM	CC	DC	EI	CM	LO	X	DIEZ,C.E & OTTENWALDER,J.A . 2000
37	TEMP.SUP.ACIMA 25°C	CC	DC	EI	X	LO	TODAS	DIEZ,C.E & OTTENWALDER,J.A . 2000
38	TEMP. SUP. DA ÁGUA > OU = 18°C	X	DC	EI	CM	LO	X	MÁRQUEZ, R. 1991
39	DISTANTE DE ESTABELECIMENTO HUMANO	X	DC	X	CM	LO	TODAS	LUCTCAVAGE & MUSICK . 1986
40	PRAIAS URBANAS	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
41	BAIXA ENERGIA DE ONDAS	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003
42	AGUAS COSTEIRAS 16 A 20°C	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
43	REFÚGIOS SUBM. FENDAS ROCHAS	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
44	REFÚGIOS SUBM. FENDAS RECIFES	X	DC	EI	CM	LO	TODAS	MILLER, J. D. et al. 2003
45	M. E. F. 4 A 8KM COSTA 3 MESES INIC DESOVA	CC	DC	EI	X	LO	TODAS	MILLER, J. D. et al. 2003
46	AG.SUP.PASTAGEM DE ALGAS	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003
47	PRÓXIMOS A LAGOAS	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003
48	PRÓXIMOS A BAÍAS	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003
49	PRÓXIMOS A MANGUES	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003
50	ESTAÇÕES QUENTES E CHUVOSAS	CC	DC	X	CM	LO	TODAS	MILLER, J. D. et al. 2003

Based on the 50 nesting habitat preferences found:

- ✓ 6 environmental variables were found to be most relevant
- ✓ Criteria for each variable were defined
- ✓ 4 classes for each variable were established (values ranging from 1 to 4).

VARIABLE



CRITERIA



4 Most suitable
3 Very suitable
2 Suitable
1 Unsuitable

VARIABLE	CRITERIA	SCORE
Artificial lighting	> 2000m (Harrison, E. & Troëng, S. 2002) 1000m – 2000m 500m – 1000m < 500m	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable
Seawater surface temperature	> 25° C (Márquez,R.1990) 20° – 25° C 18° – 20° C (Luctcavage & Musick,1985) < 18° C	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable
Plant cover	Formações Pioneiras (Mangues,veg.praia, dunas e restinga) (Mortimer,J.A.1995; Garmestani et al.2000; Miller, J.D. et all.2003;Camhi,1993) Floresta estacional semidecidual - - Floresta ombrófila Densa	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable
Beach length	> 20km (Mortimer,J.A.1995) 5 – 20 Km 500m – 5 km (Dermott,M.J.Mc.1998) < 500m	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable
Sand particle size	Coarse sand (Margaritoulis,D.2005; Garmestani et al.2000) Medium sand Fine sand (Miller,J.D et all.2003) Very fine sand	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable
Water deficit	7 a 10 meses secos (secas) (Margaritoulis,D.2005; Miller,J.D.et al.2003; Mortimer,J.A.1995) 4 a 6 meses secos (semi – úmidas) - - 0 a 3 meses secos (úmidas e super úmidas)	4 Most suitable 3 Very suitable 2 Suitable 1 Unsuitable

DATA

PRIMARY

Data collection, using GPS

Sand particle sizing from
beaches

TRANSITION
DATA

ARTIFICIAL
LIGHTING

PLANT COVER

BEACH LENGTH

SECONDARY

Remote sensing and geoprocessing

Pre-processed images already
available

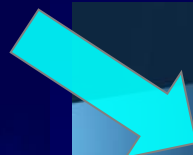
Raster images from LANDSAT
7 and AQUA – MODIS 2005

Data Base development

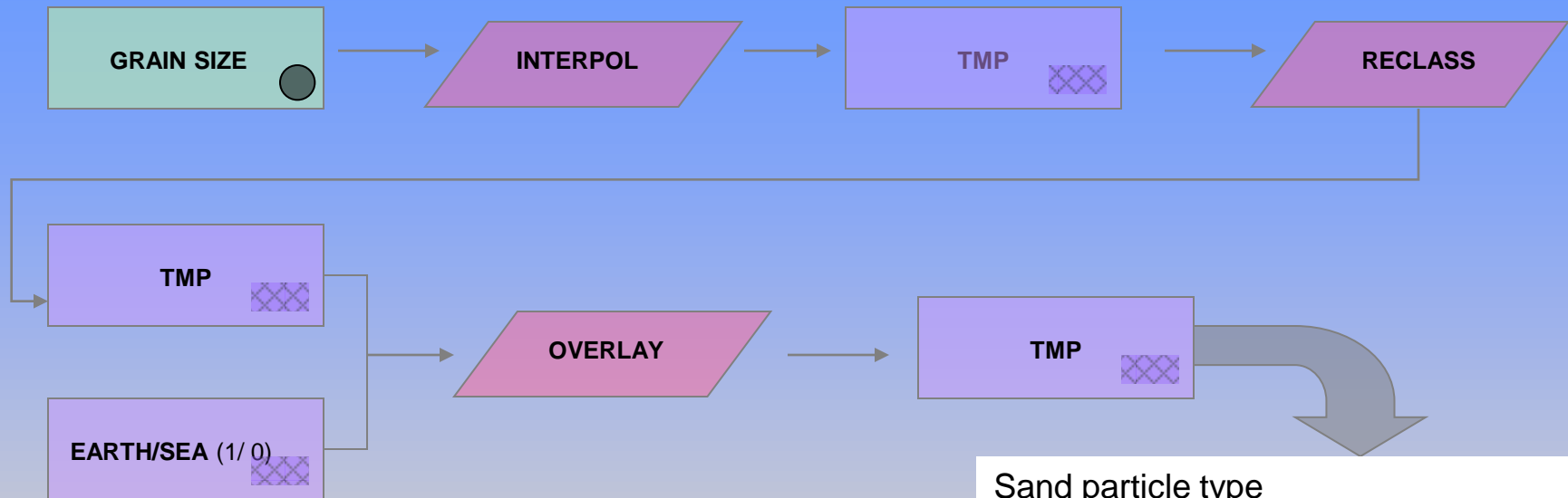


STUDY AREA

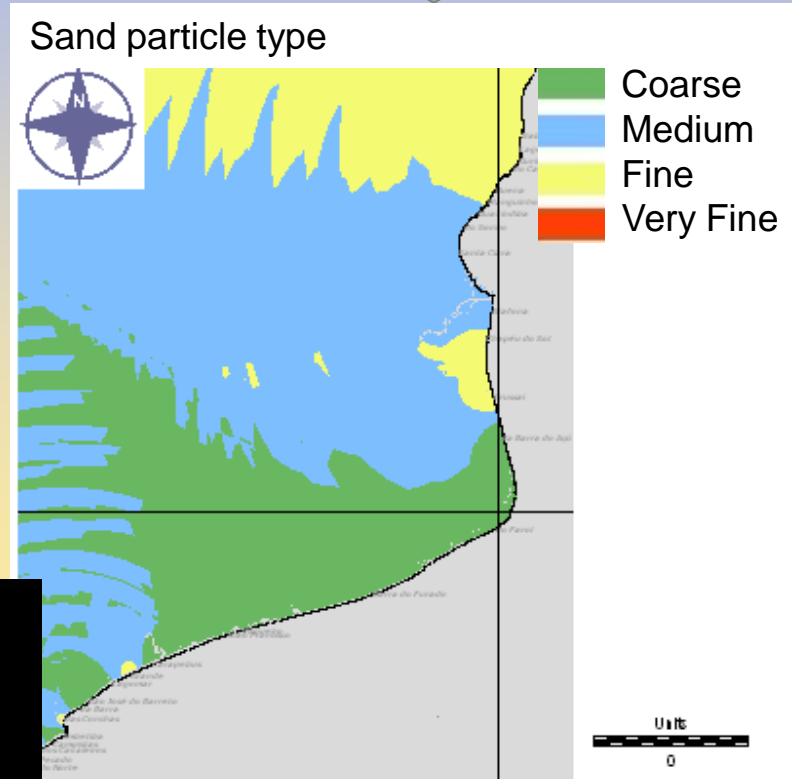
Pontos Extremos	Latitude	Longitude
Norte	20° 45' 56" S	41° 51' 40" W
Sul	23° 22' 08" S	44° 33' 33" W



SAND PARTICLE SIZING



Coarse sand is best

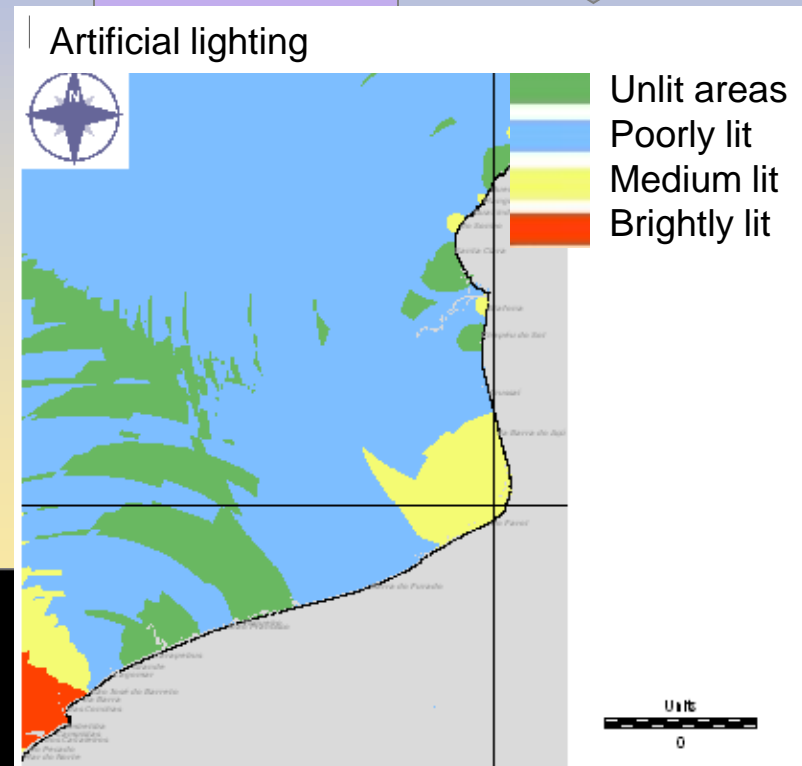
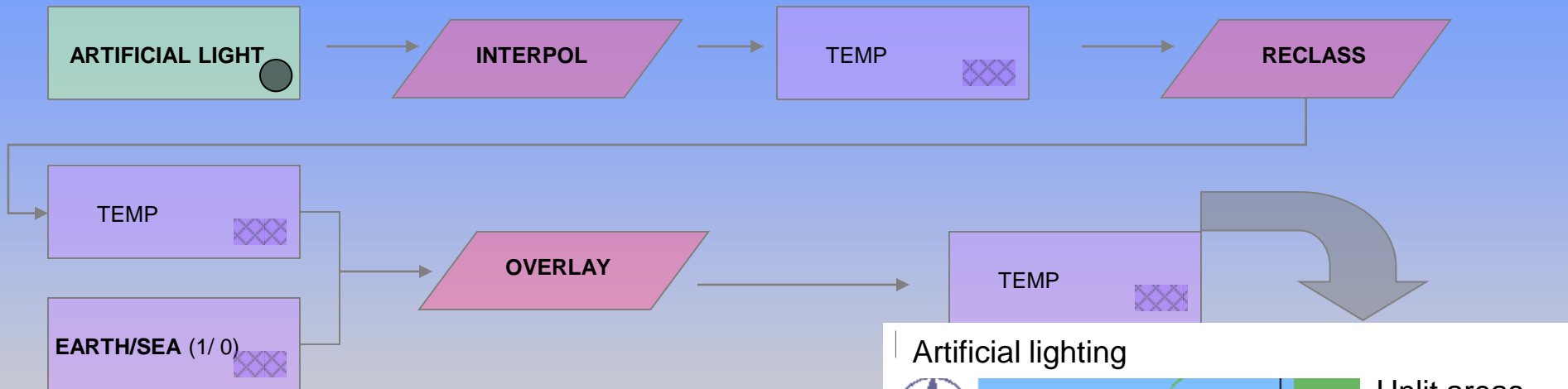


Granulometria

Areia grossa (Margaritoulis, D. 2005; Garmestani et al. 2000)
 Areia média
 Areia fina (Miller, J. D. et al. 2003)
 Areia muito fina

4 Most suitable
3 Very suitable
2 Suitable
1 Unsuitable

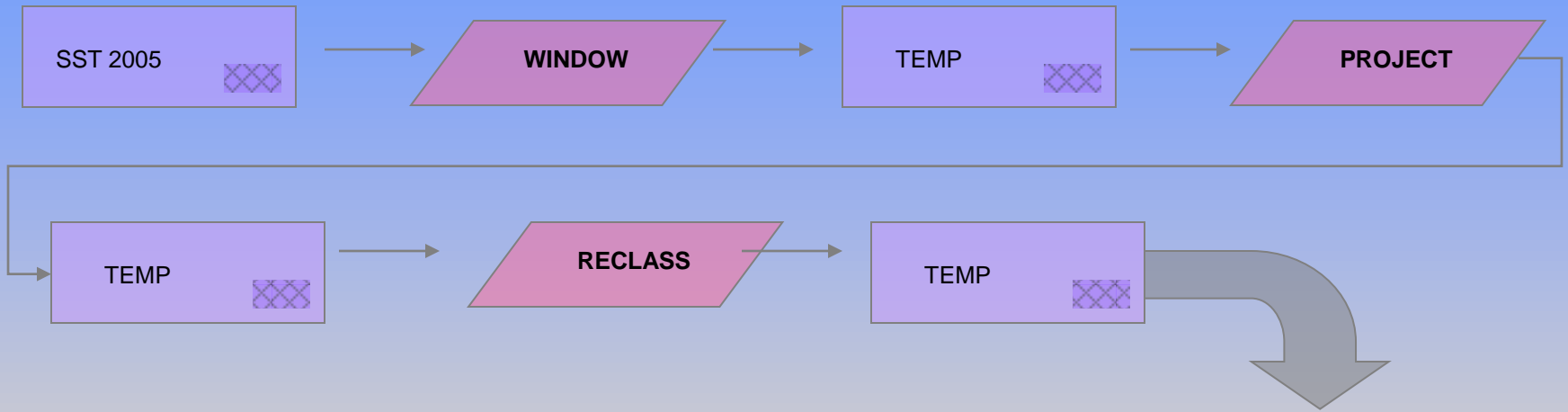
ARTIFICIAL LIGHTING



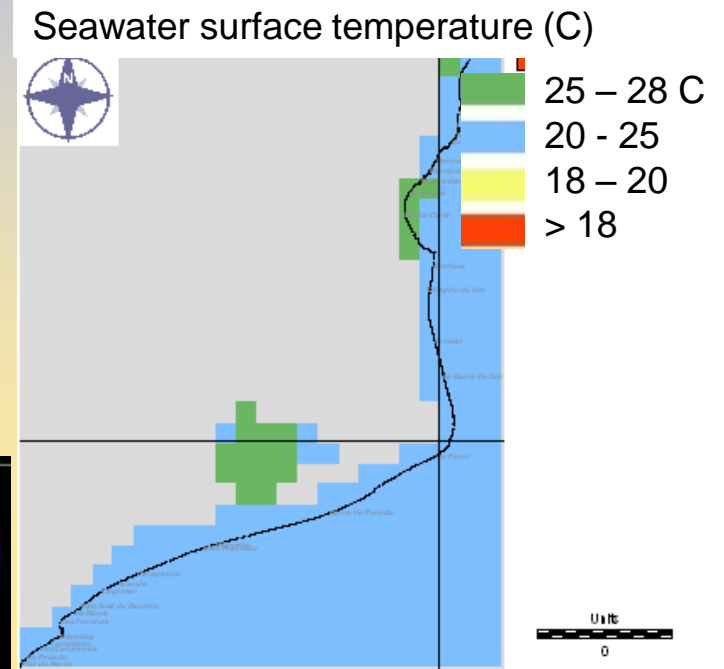
No lighting from houses or street lamps is best

Iluminação artificial	> 2000m (Harrison, E. & Troëng, S. 2002)	4 Most suitable
	1000m – 2000m	3 Very suitable
	500m – 1000m	2 Suitable
	< 500m	1 Unsuitable

SEA SURFACE TEMPERATURE

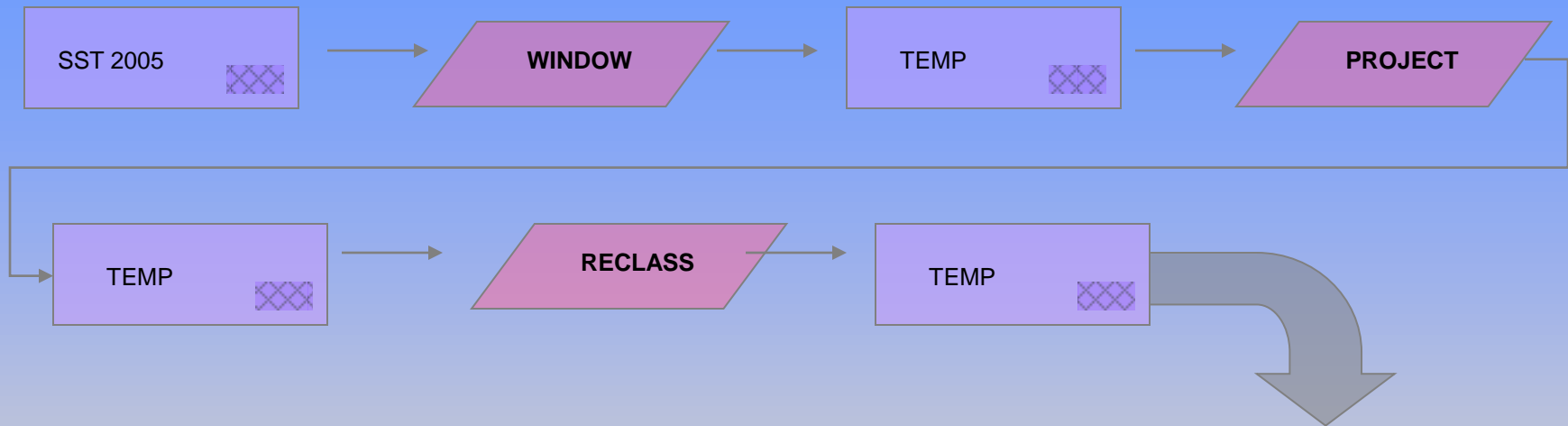


Warmer waters are more favourable

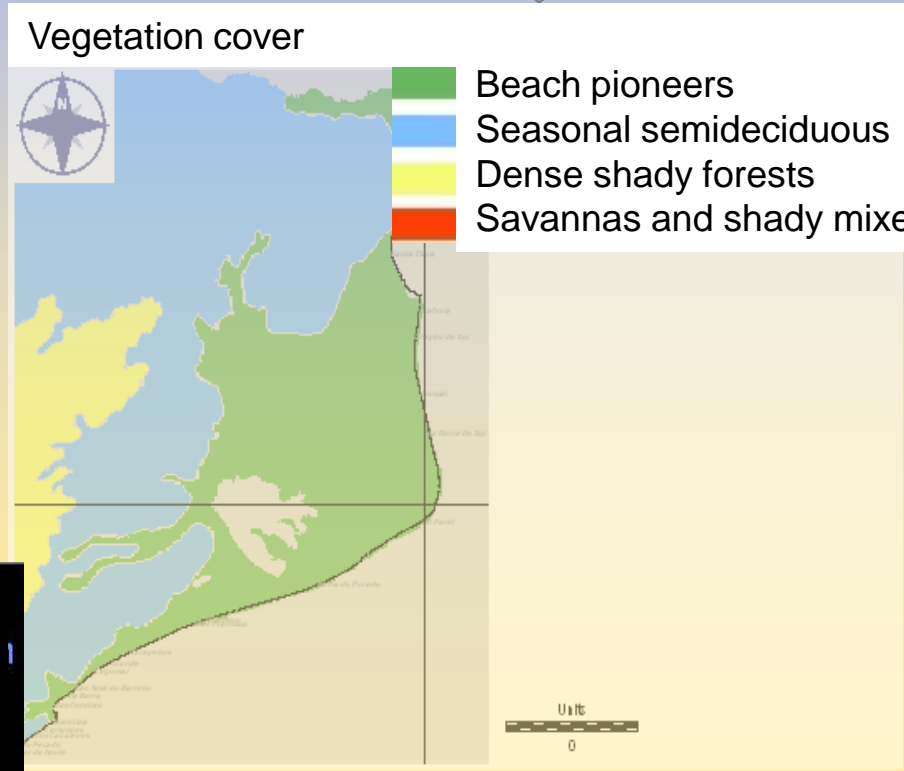


Temperatura superficial da Água do mar	> 25° C (Márquez, R. 1990)	4 Most suitable
	20° – 25° C	3 Very suitable
	18° – 20° C (Luftcavage & Musick, 1985)	2 Suitable
	< 18° C	1 Unsuitable

TYPE OF PLANT COVER



Sandy beach vegetation is best



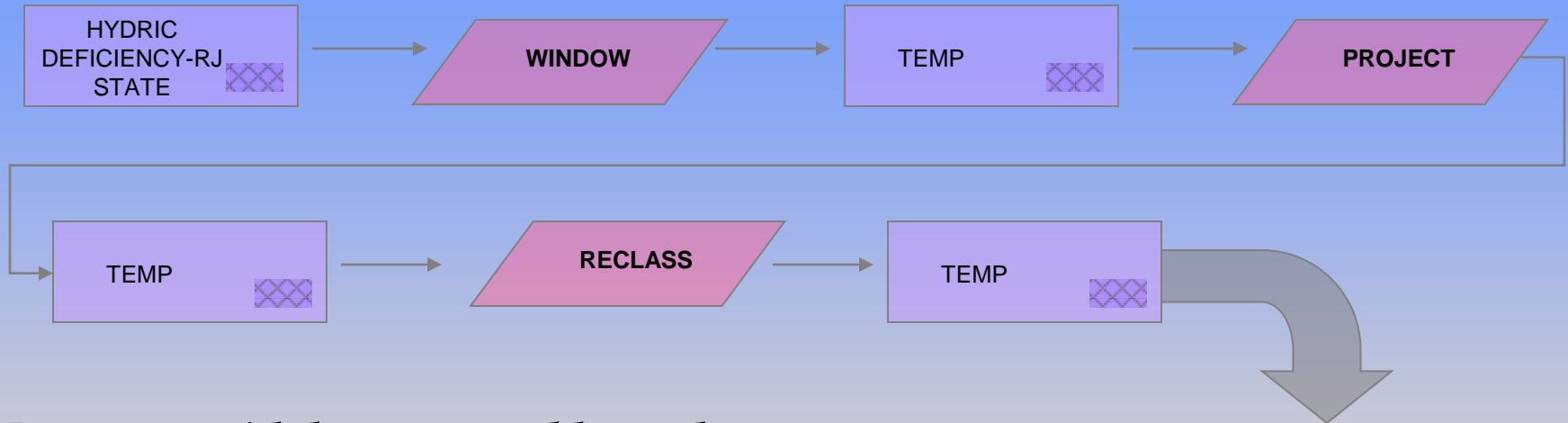
Cobertura Vegetal

Fomações Pioneiras (Mangues, veg.pi
(Mortimer, J.A. 1995; Garmestani et al. 2000; Miller, J.D. et al.)
Floresta estacional semidecidual

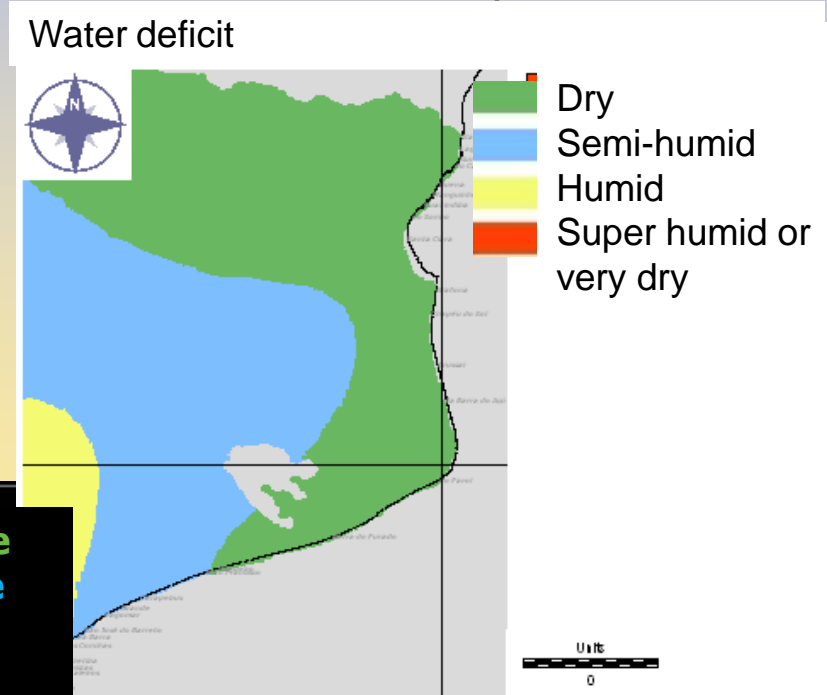
4 Most suitable
3 Very suitable
2 Suitable
1 Unsuitable

..
Floresta ombrófila Densa

WATER DEFICIT

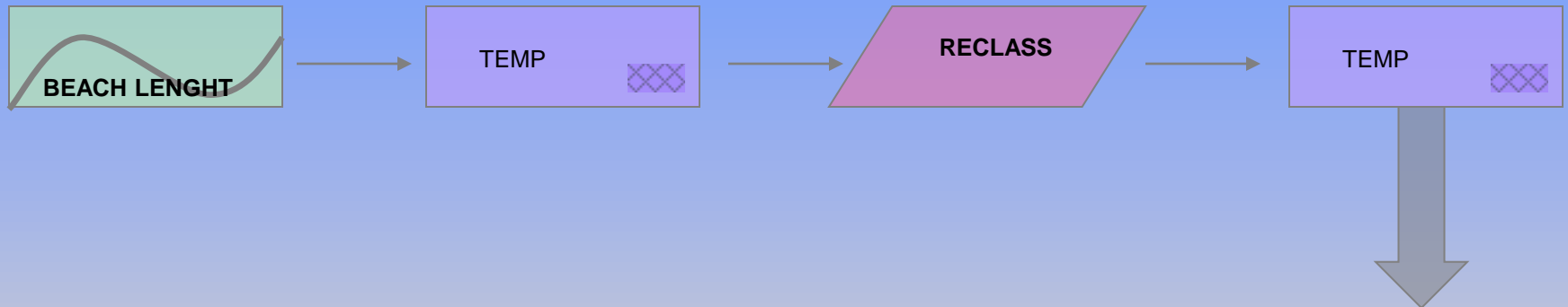


Dry areas with low water table are best

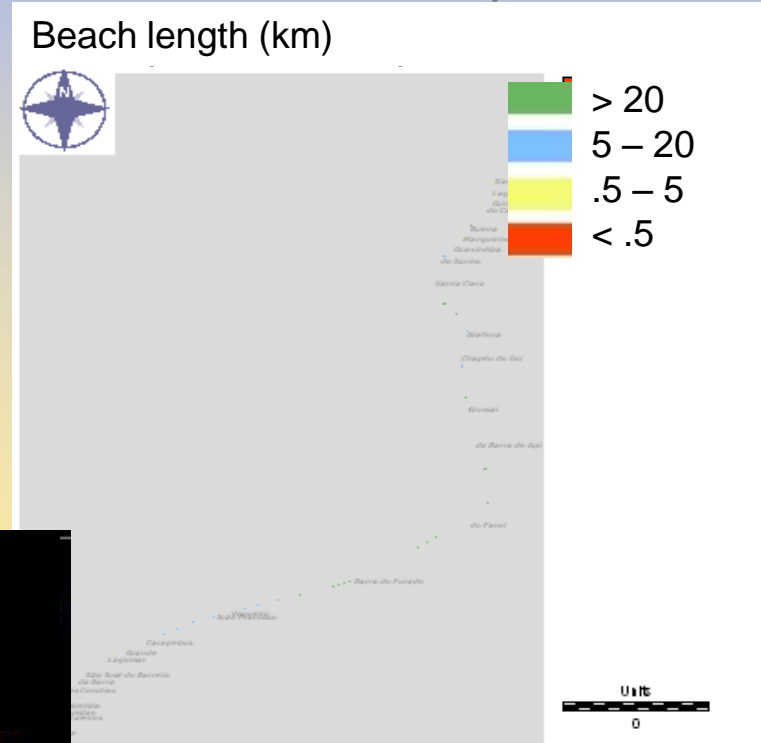


Deficiência Hídrica	7 a 10 meses secos (secas) (Margaritoulis,D.2005; Mille Mortimer,J.A.1995)	4 Most suitable
	4 a 6 meses secos (semi - úmidas)	3 Very suitable
	--	2 Suitable
	0 a 3 meses secos (úmidas e super úmidas)	1 Unsuitable

BEACH LENGTH



Long beaches are best



Comprimento de Praia	> 20km (Mortimer, J.A. 1995)	4 Most suitable
	5 - 20 Km	3 Very suitable
	500m - 5 km (Dermott, M.J. Mc. 1998)	2 Suitable
	< 500m	1 Unsuitable

RELATIONSHIP BETWEEN MODELS

- ✓ To calculate the weights of each variable the ***weight*** module of the *GIS* software was used;
- ✓ This module derives relative weight by comparing variables in pairs on a 1-9 continuous scale defining them as extremely less important to highly important.

WEIGHT DETERMINATION PROCESS

The pairwise comparison was based on the findings of previous studies

The screenshot displays the 'WEIGHT - AHP weight derivation' software interface. The main window shows a 'Pairwise Comparison 9 Point Continuous Rating Scale' with a scale from 1/9 (extremely less important) to 9 (extremely more important). Below the scale, the pairwise comparison file is named 'NORTENOVO'. A 'Calculate weights' button is visible. The pairwise comparison matrix is shown below, with red arrows indicating the comparison direction for each cell. The matrix is:

	granunorteinter	interpolurbanort	temperatnorterc	cvnorte807prjt	dhnote807prjt	praiaslinhasnort
granunorteinter	1	←				
interpolurbanort	1/3	1	←			
temperatnorterc	1	1	1	←		
cvnorte807prjt	1/5	1/7	1/7	1	←	
dhnote807prjt	1	1/3	1/3	3	1	←
praiaslinhasnort	1/5	1/5	1/7	1/3	1/7	1

Below the matrix, a text box contains the comparison: 'Compare the relative importance of temperatnorterc to granunorteinter'. At the bottom are 'OK', 'Close', and 'Help' buttons.

The 'Module Results' window on the right displays the eigenvector of weights:

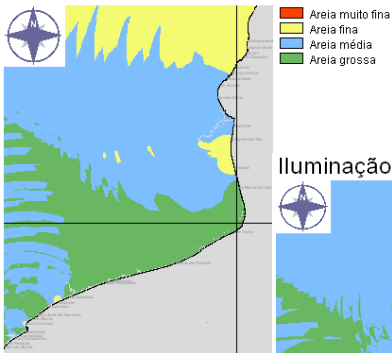
```
The eigenvector of weights is :  
granunorteinterpolrclass : 0.2722  
interpolurbanortercclassnovo : 0.2326  
temperatnortercclasspjt : 0.2699  
cvnorte807prjt : 0.0485  
dhnote807prjt : 0.1451  
praiaslinhasnortebbinaryrclass : 0.0317
```

A red circle highlights the following text in the results window:

```
Consistency ratio = 0.09  
Consistency is acceptable.
```

At the bottom of the results window are 'Print Contents', 'Save to File', and 'Cop' buttons.

Granulometria - Norte



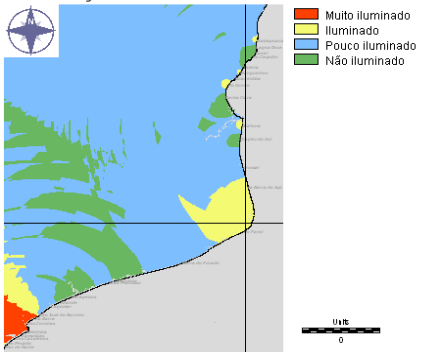
SAND PARTICLE SIZE

0.2722

Criterion

Relative weight

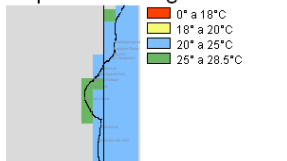
Iluminação Artificial - Norte



ARTIFICIAL LIGHTING

0.2501

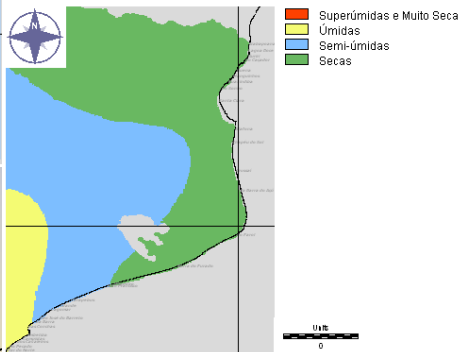
superficial da água do mar



SEA SURFACE TEMPERATURE

0.2699

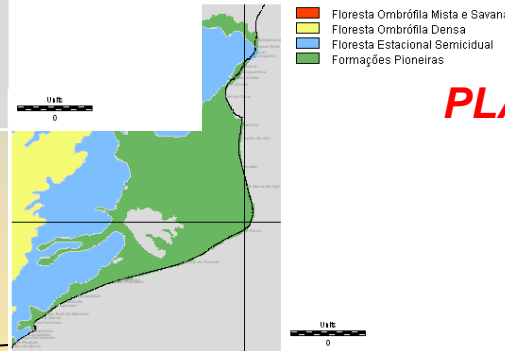
Deficiência hídrica - Norte



WATER DEFICIT

0.1451

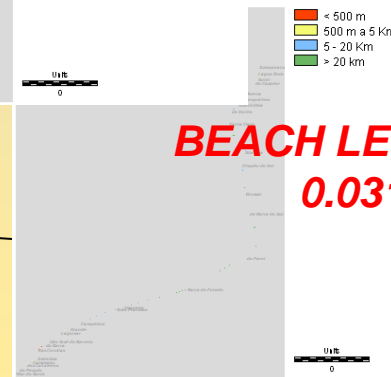
- Norte



PLANT COVER

0.0485

as - Norte



BEACH LENGTH

0.0317



Multi-criteria analysis

Results used in a Map Algebra operation

OVERLAY

*SAND PARTICLE SIZE * 0.2722*

+

*ARTIFICIAL LIGHTING * 0.2501*

+

*SEA SURFACE TEMPERATURE * 0.2699*

+

*WATER DEFICIT * 0.1451*

+

*PLANT COVERAGE * 0.0485*

+

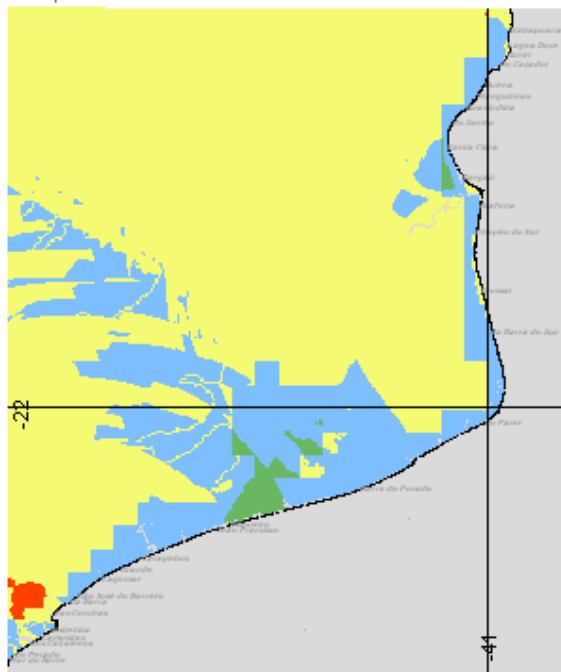
*BEACH LENGTH * 0.0317*

SUITABLE AREAS =

= PROCESSED IMAGE



NORTH AREA - RJ/BRASIL FINAL RESULT



- MAR
- REGULAR
- BOM
- MUITO BOM
- EXCELENTE

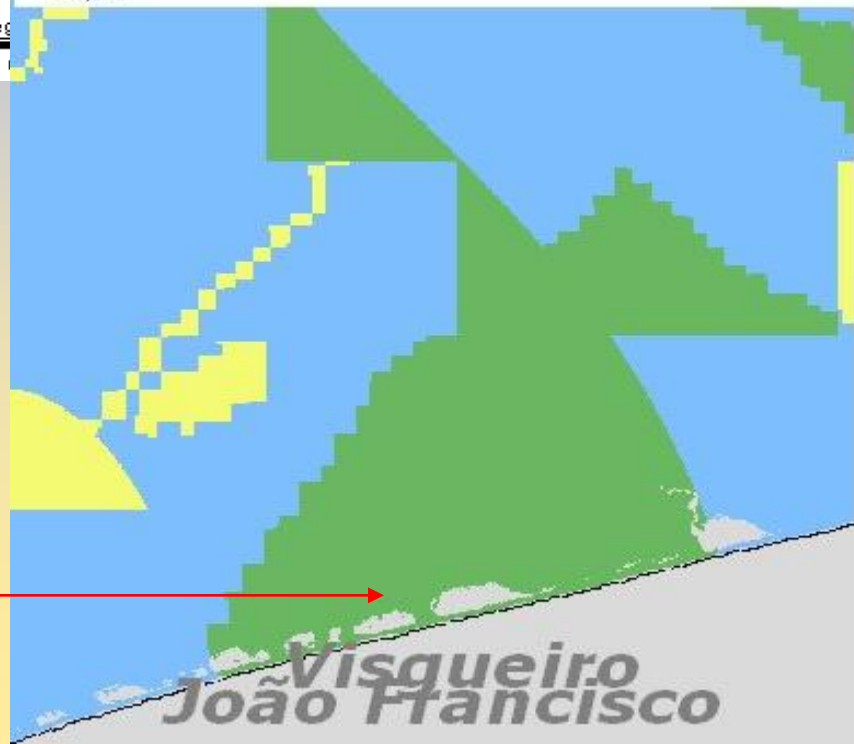
RESULTS

Beach length (km)



NORTH AREA - RJ/BRASIL FINAL RESULT

Deg



- 4 Most suitable
- 3 Very suitable
- 2 Suitable
- 1 Unsuitable

Visgueiro
João Francisco

Degrees
0



Tartaruga de Couro
(*Dermochelys coriacea*)
Comprimento: 1,20 m
Largura: 1,10 m
Cascão doado pelo
colégio de pescadores da
Praia de Armação de
Pêntano do Sul.



Tartaruga Cabeçuda
(*Caretta caretta*)



Tartaruga Verde
(*Chelonia mydas*)



Tartaruga de Pente
(*Eretmochelys imbricata*)